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DEPARTMENT OF REGISTRATION AND EDUCATION
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DIVISION OF THE
STATE GEOLOGICAL SURVEY
M. M. LEIGHTON, *Chief*
URBANA

REPORT OF INVESTIGATIONS—NO. 104

ILLINOIS SURFACE CLAYS AS BONDING CLAYS FOR MOLDING SANDS

An Exploratory Study

BY

R. M. GROGAN AND J. E. LAMAR

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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ABSTRACT

SAMPLES of surface clays from various parts of Illinois, including one sample of glacial till, twelve gumbotils and associated clays, one loess, three lake clays, seven residual clays, and three miscellaneous clays, were tested for green and dry compressive strength in parallel with several commercial bonding clays, including fireclays and bentonites, to determine their value as bonding clays for synthetic molding sands.

The compressive strength tests were made according to procedures approved by the American Foundrymen's Association. They involve determining the strength of a moist mixture of silica sand and the clay being tested or of a similar mixture which has been allowed to dry. The amounts of sand, clay, and moisture present are carefully proportioned.

The results of the tests on sand-clay mixtures containing the natural clays, unmodified except for the removal of pebbles from pebbly samples, indicate that with 8 percent clay and 2 percent moisture, six of the samples possessed green compressive strengths equal to or greater than those of three of the nonbentonitic commercial bonding clays. The dry compressive strengths of most of the surface clays equalled or exceeded those of the nonbentonitic commercial bonding clays.

The bonding ability of some clays was considerably improved by removing all the material larger than 0.002 mm. by water-classification. Tests on sand-clay mixtures containing 2 percent moisture and 8 percent of the pulverized water-separated clay concentrate from three surface clays, including two lake clays and one gumbotil, showed an increase in green compressive strength of 2 to 9½ times that of the unmodified clay. The green compressive strengths imparted by two of the clay concentrates compared favorably with green strengths given by the bentonites, 4 percent clay and 2 percent moisture being used for all tests. The dry strengths were somewhat lower than those of the bentonites.

An increase in bonding ability also resulted from the removal of coarse material from a sample of gumbotil by air-separation. Before air-classification the green compressive strength of this clay was less than that of any of the commercial bonding clays used for comparison. However, the air-separated minus 0.010 mm. fraction gave a green strength greater than any of the four nonbentonitic commercial clays using 8 percent clay and 2 percent moisture for all tests.

Air-separated fractions of a number of additional gumbotils and associated clays were also prepared. Most of the minus 0.010 mm. fractions, in sand-clay mixtures employing 8 percent of clay and 2 percent moisture, exceeded in green compressive strength the two bentonites tested at 4 percent clay, 2 percent moisture. The dry compressive strengths imparted by 8 percent of these fractions approximated those given by the bentonites at 4 percent clay.

The minus 0.050 mm. and the plus 0.050 mm. air-separated fractions generally gave lower green compressive strengths than the minus 0.010 mm. fraction at the same moisture content when 8 percent clay was used in sand-clay mixtures. The dry compressive strengths of both fractions were generally similar to those produced by the bentonites at 4 percent clay.

The green and dry compressive strengths of the samples tested are related to the relative amounts of clay-size (minus 0.002 mm.) and silt-size (0.002 mm. to 0.053 mm.) material present in the samples. In general it was found that the more clay-size material in a surface clay the higher its green compressive strength, and the more silt-size material in a clay the higher its dry compressive strength. These relations may prove useful in prospecting for bonding clay even if beneficiation by removal of sand is planned, for they appear to be true of the air-separated fractions as well as of the unmodified clays.

From the tests it appears that the Cretaceous clays tested, some residual clays, and possibly some lake clays would be suitable in their natural state, or after coarse screening, for ordinary foundry use. The other clays would need more or less beneficiation in order to compare favorably with commercial bonding clays. Some surface clays may be made to have bond strengths comparable to those of the bentonites by either hydraulic or air-classification.

Introduction

"Surface clays" are defined for this report as those clays occurring at or near the surface of the ground, including clays resulting from the weathering of bedrock. Extensive deposits of surface clays exist at many places in Illinois, but in general they are not much used commercially except locally for the manufacture of structural clay products. Because significant data are lacking regarding the suitability of these clays for purposes other than for making clay products, a study was undertaken to secure such data. A previous report [1] gave preliminary information about gumbotil, one kind of surface clay, as drilling mud, bonding clay, and bleaching clay. The present report extends the study of bonding properties to include further data regarding gumbotil as well as similar information about a number of other surface clays.

In contrast to "natural bonded" molding sands which as found in nature contain enough clay to bond them, that is, to cause the sand grains to adhere to one another, "synthetic" molding sands are prepared by adding a bonding clay to a clean sand of suitable grain size. Although natural bonded molding sands are extensively employed, synthetic sands [2] are also widely used and their use is increasing. In the Middle West the bonding clays commonly used for synthetic sands are fireclay and bentonite.

Although in the Middle West there is probably no scarcity of fireclay and other clays which can be used as bonding clay, few materials having properties which approach or equal those of bentonite are known. For this reason the work covered by this report had as its aim the discovery of Illinois surface clays whose bonding properties are better than those of fireclay and as nearly like those of bentonite as possible.

Twenty-seven typical Illinois surface clays, all of them noncalcareous, were selected for study together with six commercial bonding clays including four produced in the Middle West, a Southern bentonite from northern Mississippi, and a Western bentonite from the Black Hills area. The results of the tests on the commercial clays serve as standards for evaluating the possibilities of the Illinois materials.

[1] Lamar, J. E., Grim, R. E., and Grogan, R. M., Gumbotil as a potential source of rotary drilling mud, bonding clay and bleaching clay: Illinois Geol. Survey, Cir. 39, July 15, 1938.

[2] The term "synthetic sands" is used hereafter to denote both commercially prepared synthetic molding sands and, more commonly, the laboratory mixtures of sand and pulverized clay used in the bond clay tests.

Basis for Selection of Samples

The surface clays of Illinois may be classified into six general categories as follows: (1) till deposited by continental glaciers; (2) gumbotil produced by prolonged weathering of till under special conditions; (3) loess formed by the deposition of fine-sized wind-borne material; (4) lake clay deposited in old lake basins; (5) residual clay mostly resulting from the weathering of limestones; and (6) certain other clays, three of which are included in this investigation.

The clay samples selected for the present study comprise only a small fraction of the total number taken for the general study of Illinois surface clays. They were chosen to represent the various types of surface clays, both with respect to kind of deposit and to mineral composition. All are from deposits free from calcareous materials or are from the noncalcareous weathered portions of deposits which were originally calcareous throughout. The general location of the sampled deposits is shown in figure 1.

Bonding clays are composed of one or more of the clay minerals illite, kaolinite, or montmorillonite, plus various amounts of nonclay minerals such as quartz, limonite, and mica. Bentonites, for example, are made up dominantly of the clay mineral montmorillonite, whereas fireclays are commonly mixtures of kaolinite, illite, and quartz. Preliminary microscopic and X-ray examination indicated that a number of the surface clays contain montmorillonite. These clays were given particular attention because of the possibility that the presence of the montmorillonite might give them properties approaching those of bentonite.

In general it was necessary to take samples where favorable conditions existed, as in cuts along streams, railroads, or roads. All the samples are believed to have come from deposits of considerable size although not necessarily from the place most suitable for commercial development. They represent, therefore, the types of surface clays and surficial clay deposits occurring in Illinois, but there exist many other deposits than those tested, and any attempt at development should be preceded by a study of the relation of available deposits to market areas, followed by careful prospecting and testing of the deposits to determine their extent and character.

Distribution and Character of Surface Clay Deposits Sampled

TILL

Till is a sandy pebbly clay deposited by glaciers. Unweathered till commonly contains many limestone pebbles and other calcareous material and is therefore unsuited for use as bonding clay. During weathering, however, water percolating through the deposit dissolves and removes the calcareous material, leaving behind a noncalcareous gray or brown plastic clay better suited to foundry use. Pebbles other than those composed of limestone are also left behind to form a part of the weathered deposit. These pebbles vary in abundance from place to place.

Till is widespread in Illinois, occurring over the entire State except in extreme southern Illinois, parts of Calhoun and Carroll counties, and the northwest corner of the State. In most of northeastern Illinois the thickness of the nocalcareous till rarely exceeds 2 feet, but elsewhere the thickness may be twice that great.

Sample 48, described in the appendix, is leached till.

GUMBOTILS AND ASSOCIATED CLAYS

Gumbotil is a product of the extreme weathering of glacial till on flat uplands under conditions of poor drainage. It is a highly plastic, gray or brown clay, commonly pebbly but less pebbly than the parent till, containing silt and sand in amounts which vary widely in different localities. When dried, the clayey and silty varieties become hard and tough, whereas the sandy varieties are usually crumbly and friable.

Deposits occur in central, southern, and western Illinois. Because overburden on the gumbotil is relatively thin in south-central Illinois, the deposits in that area were

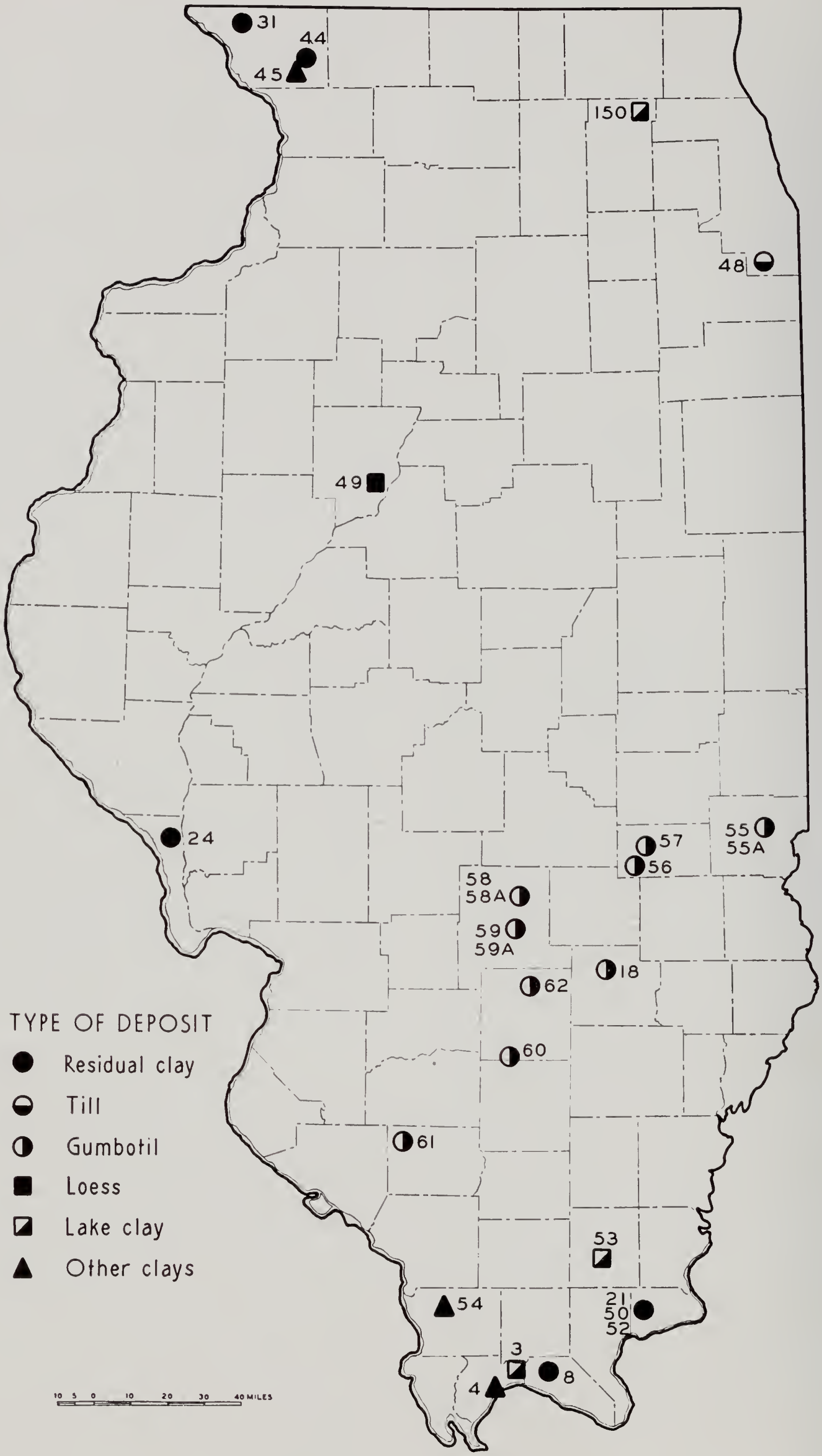

FIG. 1.—Location and type of sampled deposits of Illinois surface clays.

given more attention than those elsewhere. Samples from nine of these deposits were tested during the present study. Further details of the general occurrence, extent, and character of Illinois gumbotil deposits are given in Circular 39.[3]

Immediately below the gumbotil there is normally a zone of noncalcareous clay[4] whose character is intermediate between that of the gumbotil above and the calcareous relatively unaltered till below. As it lies immediately below gumbotil and might considerably increase the workable thickness of clay in a given area if proved suitable for bonding use, samples of this clay were taken for testing from three localities that were also sampled for gumbotil. They bear the same sample number as the gumbotils but are distinguished from them by the suffix A added to the sample number.

Descriptions of deposits sampled are given in the appendix and include samples 18, 55, 55A, 56, 57, 58, 58A, 59, 59A, 60, 61, and 62.

LOESS

Loess is a wind-deposited brown clayey silt occurring over large areas on the uplands adjacent to Mississippi, Illinois, and Ohio rivers. It is the surficial material throughout much of western and southern Illinois. The unweathered loess is commonly calcareous except in extreme southern Illinois, but the upper part of many deposits has been leached by weathering to a depth of 2 to 4 feet. Only noncalcareous loess was investigated, as calcareous material is considered deleterious in bonding clay. Sample 49, described in the appendix, is loess.

LAKE CLAYS

The lake clays studied were deposited in lakes associated with glaciers which once covered most of Illinois. These clays generally contain a considerable proportion of silt. Although the clays were calcareous when deposited, leaching has removed the calcareous material from the upper part of the deposits to a depth of 2 to 5 feet. Only the leached part of the deposits was studied.

Samples 3, 53 and 150, described in the appendix, are lake clays.

RESIDUAL CLAYS

Most of the residual clays found in Illinois have been formed by the weathering of limestone and are the insoluble materials left behind when water leached away the soluble portions of the limestone. Obviously the character of these clays is directly related to the character of the original limestones, cherty limestones giving rise to cherty clays, for example, and sandy limestones to sandy clays.

The residual clays are commonly red or brown owing to their content of hydrated iron oxides, though in a few places white or cream-colored clays have developed from limestones. Many residual clays contain angular chert fragments, although some are free from chert.

Because the downward progress of leaching is rarely uniform, it is probable that the limestone floor of most deposits is uneven, and that as a consequence the thickness of the clay in any deposit is likely to be variable. It is thought likely that residual clays are generally thickest a short distance below the tops of hills, ridges, or upland flats underlain by limestone where slumping of the clays has made their thickness greater than normal. No deposits were observed whose thickness is consistently greater than 15 feet, but exposures of clay 5 to 10 feet thick are relatively common.

The overburden on the residual clays is generally a few feet to as much as 25 feet of brown clayey silt. Considerable tonnages of clay can probably be obtained with less than 10 feet of overburden.

Residual clays occur in three principal areas in the State (fig. 1): (1) Union, Johnson, Pope, Massac, and Hardin counties in extreme southern Illinois; (2) Cal-

[3] Lamar, J. E., Grim, R. E., and Grogan, R. M. Gumbotil as a potential source of rotary drilling mud, bonding clay, and bleaching clay; Illinois Geol. Survey Cir. 39, July 15, 1938.

[4] Zone 3 of the "soil profile." For a detailed description of its character and origin see Leighton, M. M., and MacClintock, Paul, Weathered zones of the drift sheets of Illinois: Illinois Geol. Survey, Report of Investigations No. 20, 1930.

houn, Pike, and possibly some adjacent counties in western Illinois; and (3) the extreme northwest corner of the State.

Samples of typical residual clay from seven deposits were chosen for study and are described in the appendix, including samples 8, 21, 24, 31, 44, 50, and 52.

OTHER CLAYS

Three samples have been placed in this category. Sample 4 is from a deposit of Cretaceous age, sample 54 is probably of Creaceous age, and sample 45 is from a glacial deposit.

Chemical Analyses

Chemical analyses are not generally reliable guides to the bonding characteristics of clays except in a broad way. For this reason only a few analyses were made of Illinois surface clays, chiefly to supplement the information on the mineralogic and mechanical composition of some of the more promising materials studied.

Analyses of four clays are given in table 1. Silica, alumina, and combined water (loss on ignition) are the principal constituents of the clays. They reflect the presence of clay minerals, which are essentially hydrous aluminum silicates, and in some samples, the presence of free silica in the form of sand and silt.

Sample 18 shows more silica than the other samples because it contains more sand and silt (table 1). The total soda and potassia in each sample is in a large degree an indication of the relative amounts of soda- and potash-bearing clay minerals, such as illite and montmorillonite, in that clay. The chief clay mineral present in the kaolin is kaolinite, which contains very little soda and potassia.

Preparation of Samples for Testing

The commercial bonding clays (excepting the bentonites) were received in lump form and were ground in a disc pulverizer in preparation for bond tests. The bentonites were received already ground.

The samples of surface clays were prepared for testing by one of three methods: (1) grinding all of that part of the sample which passed a 4-mesh sieve; (2) concentrating and removing from the original sample by water-separation that fraction composed of particles less than 0.002 mm. in diameter, followed by drying and grinding; and (3) air-separating three size fractions from pulverized clay from which the plus 4-mesh material had been removed before grinding.

Table 1.—Chemical Analyses of Surface Clays[a]

	Sample[b] 4	Sample[c] 18	Sample 21	Kaolin[d]
SiO_2	59.60	79.04	56.96	51.10
TiO_2	0.72	0.51	0.37	0.95
Al_2O_3	26.48	11.04	23.47	34.01
Fe_2O_3	2.39	3.47	8.84	1.41
MnO	...	0.03	...	...
MgO	0.77	0.72	0.82	0.37
CaO	0.44	0.39	0.53	0.15
Na_2O	0.37	0.85	0.30	0.36
K_2O	1.67	1.45	1.56	0.31
Loss on ignition	8.03	3.18	7.92	11.95
Total	100.47	100.65	100.77	100.61

[a] Analyses made under the direction of O. W. Rees, State Geological Survey.
[b] Sample 4, Cretaceous clay; 18, gumbotil; 21, residual clay; Kaolin, Cretaceous clay.
[c] Average of two analyses.
[d] Analysis of crucible clay from deposit near Kaolin Station, Union County, similar to sample 54.

PULVERIZED NATURAL AND DE-PEBBLED CLAYS

The first method involved air-drying, breaking of lumps, and thorough mixing of the field sample, after which a small representative portion was separated by a Jones-type sample splitter and set aside for mechanical analysis. If the sample contained pebbles these were removed by hand-picking. The plus 4-mesh material thus segregated was weighed and discarded. About 15 pounds of the pebble-free material, or of the original sample if it contained no pebbles, was then ground in a disc pulverizer, and the resulting product was used in bonding tests. In discussing results of these tests samples prepared as indicated above are referred to as "natural" if they contained no pebbles and as "de-pebbled" if pebbles were removed. Mechanical analyses of the original field samples are given in table 2. Sieve analyses of the pulverized samples are given in table 3.

CLAY CONCENTRATES

The upper size limit of the material that is believed to consist largely of clay minerals in the samples studied is about 0.002 mm. The amount of this material is less than 40 percent in many of the samples. To determine the properties of this clay mineral material, especially in samples appearing to contain montmorillonite, the minus 0.002 mm. fractions of samples 3, 18, and 150 were separated by suspending the sample in water to which a small amount of sodium oxalate had been added to insure dispersion of the clay mineral material, and after an appropriate settling period the minus 0.002 mm. material in suspension was siphoned off. The clay mineral concentrates thus obtained were dried and pulverized in preparation for use in bonding tests.

AIR-SEPARATED FRACTIONS

By means of a laboratory air classifier, selected samples that had been previously pulverized after removing any pebbles present, were sized to three fractions: minus 0.010 mm., 0.010 to 0.050 mm., and plus 0.050 mm., which is roughly plus 270-mesh. Microscopic examination showed a small amount of particle size overlap between fractions.

Average yields of the three air-separated fractions for each sample are given in table 4. The results of hydrometer analyses of unground clay and the air-separated fractions for samples 18, 59, and 59A are given in table 5.

A comparison of the data in table 4 and the results of hydrometer analyses of the unground samples and minus 0.010 mm. fractions, table 5, indicates that only 26 and 27 percent, respectively, of the minus 0.010 mm. material in samples 18 and 59, and 63 percent of that in sample 59A was actually recovered by air-separation. This is thought to be due partly to imperfect separation of particles of various sizes in the air classifier, but more largely to incomplete disintegration of samples during grinding. Minus 0.010 mm. material is present in the plus 0.010 mm. fractions, both as particles below 0.010 mm. in size which were not removed by air-separation, and as particles bound up in aggregates not completely disintegrated into minus 0.010 mm. particles during grinding. Commercial processes are probably available which would achieve better disintegration of samples and thus permit greater recovery of minus 0.010 mm. material than was possible with the laboratory equipment employed in this work.

Calculations based on the data in tables 4 and 5 indicate that a minor amount of plus 0.010 mm. material was reduced to minus 0.010 mm. size as a result of the grinding procedure used.

Bonding tests were made on the three air-separated fractions: minus 0.010 mm.; minus 0.050 mm. (obtained by recombining parts of the minus 0.010 mm. and 0.010 mm. to 0.050 mm. fractions in their proper proportions) ; and plus 0.050 mm.

TABLE 2.—LOCATION AND THICKNESS OF DEPOSITS SAMPLED AND MECHANICAL ANALYSES OF FIELD SAMPLES OF SURFACE CLAYS

Sample No.	Sample Location		Thickness in feet	Mechanical analysis[1]; percent				Mechanical analysis on pebble-free basis; percent		
	County	Near		Clay —0.002 mm.	Silt —270 mesh +0.002 mm.	Sand —4 mesh +270 mesh	Pebbles +4 mesh	Clay —0.002 mm.	Silt —270 mesh +0.002 mm.	Sand —4 mesh +270 mesh
Till										
48	Cook		2	31.0	39.5	22.8	6.7	33.2	42.4	24.4
Gumbotils and associated clays										
18	Clay	Louisville	3½	31.4	39.1	28.8	0.7	31.6	39.4	29.0
55	Clark	Marshall	3	25.9	31.8	39.4	2.9	26.7	32.7	40.6
55A	"	"	2⅔	20.3	29.3	47.9	2.5	20.8	30.1	49.1
56	Cumberland	Montrose	5	28.8	39.3	30.7	1.2	29.1	39.8	31.1
57	"	Toledo	4	22.0	57.6	20.4	trace	22.0	57.6	20.4
58	Fayette	Brownstown	2	31.1	26.9	39.4	2.6	31.9	27.6	40.5
58A	"	"	3	20.6	25.2	46.9	7.3	22.2	27.2	50.6
59	"	"	2½	33.6	27.4	37.8	1.2	34.0	27.7	38.3
59A	"	"	3½	22.0	24.0	51.2	2.8	22.6	24.7	52.7
60	Jefferson	Walnut Hill	2¾	26.2	63.1	10.7	0.0	26.2	63.1	10.7
61	Perry	Swanwick	2⅓	31.0	48.0	21.0	trace	31.0	48.0	21.0
62	Marion	Kinmundy	2½	30.6	49.7	19.7	trace	30.6	49.7	19.7
Loess										
49	Peoria	Bartonville	2⅔	39.2	60.6	0.2	0.0	39.2	60.6	0.2
Lake clays										
3	Pulaski	Karnak	5½	35.6	58.6	5.8	0.0	35.6	58.6	5.8
53	Saline	Harrisburg	2½	44.7	52.3	3.0	0.0	44.7	52.3	3.0
150	Kane	Gilberts	2½	35.3	60.0	4.7	0.0	35.3	60.0	4.7

			Residual clays							
8	Massac	Mermet	2	36.6	16.8	13.4	33.2	54.8	25.2	20.0
21	Hardin	Eichorn	7	68.6	14.6	11.3	5.5	72.6	15.5	11.9
24	Calhoun	Kampsville	8	19.4	35.0	18.1	27.5	26.8	48.2	25.0
31	Jo Daviess	Council Hill	3	52.0	47.0	1.0	0.0	52.0	47.0	1.0
44	"	Stockton	4	45.2	54.0	0.8	0.0	45.2	54.2	0.8
50	Hardin	Eichorn	6½	45.9	24.5	10.6	19.0	57.6	30.2	13.1
52	"	"	6	56.8	28.0	8.5	6.7	60.9	30.0	9.1
			Other clays							
4	Pulaski	Grand Chain	13	70.6	29.4	trace	0.0	70.6	29.4	trace
45	Jo Daviess	Stockton	4	45.1	50.2	3.3	1.4	45.7	50.9	3.4
54	Union	Anna	Pit run	70.5	24.8	4.7	0.0	70.5	24.8	4.7
			Commercial bonding clays							
A	...	...	...	62.5	34.4	3.1	0.0	62.5	34.4	3.1
B	...	...	...	48.0	50.4	1.6	0.0	48.0	50.4	1.6
C	...	...	...	64.5	34.2	1.3	0.0	64.5	34.2	1.3
D	...	...	...	56.4	43.6	trace	0.0	56.4	43.6	trace

Southern bentonite / Western bentonite } Probably more than 80 percent finer than 0.002 mm.

[1] Amount of clay determined by sedimentation using sodium oxalate as deflocculant and the amount of silt and sand by wet sieving the material from which the clay had been removed.

Table 3.—Sieve Analyses of Disc-pulverized Natural and De-pebbled Clays

Sample No.	Percent retained				
	+65 mesh	—65 mesh +100 mesh	—100 mesh +150 mesh	—150 mesh +200 mesh	—200 mesh
			Till		
48	2.1	15.6	11.5	11.3	59.5
			Gumbotil		
18	1.3	12.5	12.7	10.8	62.7
			Loess		
49	1.1	3.0	2.0	3.8	90.1
			Lake Clays		
3	2.2	6.3	8.5	12.1	70.9
53	trace	0.2	2.2	7.7	89.9
150	5.9	14.4	6.3	5.3	68.1
			Residual Clays		
8	0.5	13.3	12.7	11.8	61.7
21	0.6	6.7	9.7	14.0	69.0
24	0.6	7.2	7.2	7.2	77.8
31	0.0	2.5	7.2	9.3	81.0
44	0.2	6.1	7.8	9.1	76.8
50	0.0	2.3	6.2	10.9	80.6
52	trace	0.6	3.1	7.6	88.7
			Other Clays		
4	0.0	0.3	2.3	7.2	90.2
45	1.4	11.4	8.1	8.0	71.1
54	trace	4.4	5.6	7.5	82.5
			Commercial Bonding Clays		
A	2.7	12.4	9.3	8.5	67.1
B	0.7	9.6	8.3	8.3	73.1
C	0.3	6.6	10.2	9.6	73.3
D	trace	8.2	10.1	8.5	73.2
Southern bentonite, Western bentonite	......90 percent or more through 200 mesh as received.				

Table 4.—Results of Air-classification of Ground Surface Clays

Sample No.	Percent of given size fraction yielded[1]			
	—0.010 mm.	0.010 mm. to 0.050 mm.	+0.050 mm.	Total —0.050 mm.
18	11.8	21.5	66.7	33.3
55	14.4	15.7	69.9	30.1
55A	18.8	13.5	67.7	32.3
56	11.0	19.9	69.1	30.9
57	15.1	42.8	42.1	57.9
58	13.6	15.9	70.5	29.5
58A	14.9	11.9	73.2	26.8
59	11.4	15.5	73.1	26.9
59A	13.1	10.7	76.2	23.8
60	11.1	43.4	45.5	54.5
61	10.5	28.7	60.8	39.2
62	11.0	30.1	58.9	41.1

[1] In most cases the figures shown are the averaged results of more than one operation of grinding and air-separation.

TABLE 5.—PARTICLE SIZE DISTRIBUTION OF SELECTED GUMBOTILS AND ASSOCIATED CLAYS AND OF AIR-SEPARATED FRACTIONS FROM THE SAME SAMPLES.[1]

Sample No.	Percent of given size fraction			
	—0.010 mm.	0.010 mm. to 270 mesh	270 mesh to 14 mesh	+14 mesh
		Unground clay		
18	39	33	26	2
59	36	28	33	3
59A	18	25	35	22
		Minus 0.010 mm. air-separated fraction		
18	86	14	0	0
59	85	15	0	0
59A	86	14	0	0
		0.010–0.050 mm. air-separated fraction		
18	49	50	1	0
59	50	48	2	0
59A	39	58	3	0
		Plus 0.050 mm. air-separated fraction		
18	34	25	41	0
59	29	20	51	0
59A	12	17	70	1

[1] The amounts of materials finer than 270 mesh were determined by hydrometer analyses; the amounts of coarser materials by wet sieving the samples used for the hydrometer analyses.

TESTING SAND

The sand used for testing was banding sand from the Ottawa, Illinois, district. The average of four sieve tests is given in table 6.

Some variation in grain size was shown between different bags and lots of the sand. These variations, however, produced no effects of observable significance.

TABLE 6.—AVERAGE SIEVE TEST OF TESTING SAND

Mesh	Percent retained
48	22.7
65	33.6
100	31.8
Pan	11.9
	100.0

TESTING PROCEDURE

Green compressive strength, dry compressive strength, moisture, and green permeability determinations were made on mixtures of sand, pulverized clay, and distilled water. Standard A.F.A. specifications for these tests[5] were followed with a few minor exceptions, notably the omission of a dummy batch during mulling and the use of a sample of 100 grams instead of 50 grams in moisture determinations. The equipment used for all tests was of standard design. Moisture was determined with a "moisture teller." Green permeability was measured by the orifice method.

All the commercial bonding clays except the bentonites, all the surface clays, and all the air-separated fractions except those of plus 0.050 mm. size and one sample (18) of minus 0.010 mm. size were tested using 8 percent of the clay material. The plus 0.050 mm. air-separated fractions were used at 20 percent because they failed to give satisfactory results at 8 percent. The bentonites and the water-separated clay concentrates were used at 4 percent because

[5] American Foundrymen's Association, Testing and Grading Foundry Sands and Clays: 4th Ed., pp. 29-31, 32-38, 42-45, 61-62, 109-111, 122-125, 129-132, 1938.

bentonites are commonly reported to be used in about that amount in actual foundry practice.

Results of Tests

In the present study a working standard of comparison for estimating the probable usefulness of Illinois surface clays was obtained by testing four commercial non-bentonitic bonding clays and two commercial bentonites in the same manner as the surface clays.

The bentonites included one sample of Western bentonite from the Black Hills region and one sample of Southern bentonite from northern Mississippi.

In presenting the results of tests and discussing such data it is necessary to indicate the percentage of the sample used in making the tests. Usually the amount is 8 percent but in some cases 4 percent. For brevity the expression "8 percent clay" or "4 percent clay" is used to describe the amount of the sample employed, and when so used has no mineralogical or compositional significance although in most cases the sample would ordinarily be described as clay.

The results of green compressive strength tests for all samples and of dry compressive strength for all samples except 18, 24, 48 and 150, which were not tested for dry strength, are given in table 7. These results are shown graphically in figures 2A and 2B by curves joining points representing green and dry compressive strengths plotted against moisture contents. The strengths corresponding to certain moisture contents as indicated by the curves are compiled in table 8, to facilitate a comparison between samples. In table 8 the samples are arranged in order of decreasing green compressive strength at 2 percent moisture. This moisture content was chosen as a basis for comparison because it is closest to the optimum for many of the clays tested and because the synthetic sands which contained less than 2 percent moisture were too dry to "work" well, even though they had higher green strength than they did at 2 percent moisture.

Interpretation of Test Data

In the discussion of test data which follows frequent reference is made to samples by sample number. In order to facilitate correlation of these sample numbers with the kind of clay composing them and their general geographic location, an index to samples is included in table 9.

NATURAL AND DE-PEBBLED CLAYS

Green compressive strength.—The green compressive strengths of synthetic sands made with the six surface clays 4, 8, 21, 31, 52, and 54 (table 8) exceeded or otherwise compared favorably with those given by sands containing the commercial bonding clays B, C, and D, but did not equal those given by the mixture made with A. Samples 3, 44, 45, 50, and 53 may also have possibilities. The lower green strengths imparted by the remaining five clays indicate that in their natural state they are probably of the least importance of the clays tested. Of the eleven samples listed above, six are residual clays, two are lake clays, two are Cretaceous clays and one is glacial clay.

Dry compressive strength.—The dry compressive strengths of synthetic sands made with surface clays 3, 31, 44, 49 and 53 were consistently greater than those of sands made with the commercial clays A, B, C, and D. The strengths of samples 4, 8, 21, 45, and 50 were within the range shown by the commercial clays; clays 52 and 54 were somewhat weaker. No tests were made on samples 18, 24, 48, and 150 because their low green strengths made them seem unpromising. Of the first ten samples mentioned above, five are residual clays, two are lake clays, one is loess, one is glacial clay and one is Cretaceous clay.

Compressive strength and content of minus 0.002 mm. material.—A comparison of tables 2 and 8 shows that in general the more minus 0.002 mm. material a sample contains the higher is its green compressive strength. Conversely, a large content of minus 0.002 mm. material is in many cases accompanied by a relatively low dry compressive strength. Silt has the opposite effect

on dry compressive strength as samples containing relatively large amounts of silt tend to have greater dry strength though this relationship is not altogether consistent.

Mineral composition.—Examination by means of the microscope and the X-ray[6] have demonstrated the presence of two and commonly three of the clay minerals, kaolinite, illite, and montmorillonite, in appreciable amounts in every sample excepting the kaolin from Union County, sample 54, which is dominantly kaolinite[7]. Thermal analyses of twelve samples, 3, 4, 8, 21, 24, 44, 50, 52, 56, 58, 58A, and 62 showed the probable additional presence of halloysite, and it is possible that halloysite occurs in similar samples for which no thermal analyses were made.

Accurate quantitative methods are not available for the determination of the relative amounts of the various clay minerals in complex mixtures such as occur in surface clays. Until such methods are devised it is not feasible to attempt correlation of the bonding properties of the surface clays with their clay mineral composition.

CLAY CONCENTRATES

The studies of clay concentrates were made to determine whether superior bonding clays could be produced by hydraulic classification of surface clays so as to eliminate all materials coarser than 0.002 mm. and thus produce a concentrate of the clay mineral material present.

Green compressive strength.—The green compressive strengths of synthetic sands containing 4 percent of minus 0.002 mm. clay concentrates from samples 18 and 150, see table 8, were approximately the same as those given by 4 percent of the Western bentonite, table 8, but were lower than the values for the Southern bentonite. The clay concentrates from sample 3 showed less strength than the bentonites, indicating that more than 4 percent of this clay concentrate would be necessary to produce equivalent strengths.

Dry compressive strength.—The dry compressive strengths imparted by the clay concentrates from samples 3, 18, and 150 at 4 percent clay were somewhat lower than those produced by the bentonites. This may be an advantage for certain foundry uses.

Effect of eliminating material larger than 0.002 mm.—An increase in the green compressive strengths of clays from which particles larger than 0.002 mm. have been removed is indicated by a comparison of the green compressive strengths of synthetic sands made with 8 percent of the de-pebbled or natural surface clays and with 8 percent of the clay concentrates from the same clays, measured at comparable moisture contents, table 10. It is probable that the green compressive strength of other surface clays containing relatively small or moderate amounts of minus 0.002 mm. material might likewise be improved by a similar removal of the sand and silt which they contain.

AIR-SEPARATED FRACTIONS

The investigation of the properties of three size fractions (tables 4 and 5) produced from pulverized surface clays by air-separation was made to explore the possibility of producing superior bonding clays by this method and to determine the possible usefulness of any resulting byproducts. An upper size limit of 0.010 mm. was chosen for the finest fraction because material that size and finer has a high clay mineral content and because a separation at that size may be a commercial possibility.

A second size limit of 0.050 mm. was chosen because material that size or finer is essentially a sand-free clay. This fraction is referred to as the minus 0.050 mm. fraction and includes all material finer than 0.050 mm.

The plus 0.050 mm. fraction is a byproduct of the air-separation. Tests were made to determine its possible usefulness as a molding sand, either when used alone or with the addition of other sand.

[6] Microscopic examinations and thermal analyses were made by the Petrographic Division of the State Geological Survey and X-ray analyses were made by W. F. Bradley also of the Survey.

[7] Grim, R. E., Personal communication. Even this clay may be a mixture of kaolinite and halloysite.

Green compressive strength.—At 8 percent clay and 2 percent moisture, the minus 0.010 mm. fractions separated by air-classification from 10 samples gave green compressive strengths (table 8) equal to or greater than commercial bonding clays B and D. Six gave green strengths equal to or exceeding the strength of clay C. Seven exceeded bonding clay A at 2 percent moisture but only one had a green strength equal to the optimum strength of clay A. To afford a direct comparison with the bentonites, sample 18 was used in synthetic sands containing 4 percent clay instead of the usual 8 percent. The resulting green strengths were considerably lower than those given by the bentonites at 4 percent clay. As the strengths of sands made with 8 percent of this sample and of ten others exceeded those given by the bentonites at 4 percent clay and 2 percent moisture, it is concluded that strengths approximating those of the bentonites would have been obtained by using an amount of minus 0.010 mm. material between 4 and 8 percent.

The minus 0.050 mm. fractions of the six samples tested gave lower green strengths at the same moisture contents than the minus 0.010 mm. fractions of the same samples. At 2 percent moisture one sample gave a green strength which exceeded the strength of clays B and D but no sample gave a green strength equal to that of clays C or A. One sample, 59, gave at 8 percent clay a green compressive strength which exceeded that of the bentonites at 2 percent moisture and 4 percent clay; the others gave strengths approximately equal to the bentonites.

The tests on the plus 0.050 mm. fractions, approximately plus 270 mesh, are not directly comparable with the results of any of the other tests because they represent the use of from 2½ to 5 times as much clay-bearing material in synthetic sands as was used in testing other samples. They are interesting, however, in that they show that some degree of bonding power is retained in the sand-size portion of the air-classified clays, presumably as a coating on the sand grains and in undisintegrated clay pellets. It is possible that the efficiency of grinding could be improved commercially so as to release into the finer sizes much of the clay (see table 5) which remained in the coarse fraction.

Dry compressive strength.—The dry compressive strengths imparted by 8 percent of all three fractions were in general greater than those given by commercial bonding clays A, B, C, and D, and practically all of them fell within the range of dry strengths shown by the Western and Southern bentonites at 4 percent.

Permeability.—Permeabilities were measured on synthetic sands containing the air-separated fractions but not on synthetic sands containing bentonites or the other commercial bonding clays. The data, table 8, show that synthetic sands made with 8 percent of the minus 0.010 mm. fractions had generally higher permeabilities than those prepared with minus 0.050 mm. fractions. The probable explanation is that the fine clayey material of the minus 0.010 mm. fraction tends to coat the sand grains leaving clear much of the intergrain space, whereas in the case of the minus 0.050 mm. fractions the abundant silt-size particles (mostly nonclay material) tend to clog the spaces between sand grains and thereby reduce permeability.

The permeabilities bear no recognizable relation to the relative amounts of clay, silt, or sand in the clays from which the air-separated fractions were obtained. They may, however, bear some relation to the size distribution of particles within the air-separated fractions although this is not evident from the data at hand (table 5).

General effect of different size fractions.—In the tests on the air-separated fractions of samples 18, 55A, 58A, 59, 59A, and 62, the minus 0.050 mm. fractions gave lower green compressive strengths than the corresponding minus 0.010 mm. fractions, and it appears likely that the plus 0.050 mm. fractions would have given still lower green compressive strengths had they been used in the proportion of 8 percent instead of 20 percent in making synthetic sands. Hence the general effect of increasing the proportion of material larger than 0.010 mm. is the lessening of bonding ability, as if the

strength giving part of the sample were being diluted with relatively inert material.

A specific example of the general relationships mentioned above is supplied by the data on sample 18 which includes figures on the green and dry compressive strengths of the de-pebbled clay as well as on the strengths imparted by the three air-separated fractions and the minus 0.002 mm. fraction or clay concentrate obtained by water separation. For convenience table 11 shows these data assembled from their various places in table 8, and also data from tables 2 and 5 on the percent of each type of material present in the original sample. When compared on the common basis of 2 percent moisture, the data show that whereas 4 percent of the minus 0.010 mm. fraction gave essentially the same green strength as 8 percent of the de-pebbled clay, 8 percent increased the green strength almost five times. The following facts are also of importance: 8 percent of the minus 0.050 mm. fraction gave double the green strength resulting from the use of the same amount of de-pebbled clay; 8 percent of the minus 0.010 mm. fraction gave nearly the same green strength as 2½ times as much of the plus 0.050 mm. fraction; 4 percent of the clay concentrate gave over two times the green strength imparted by 4 percent of the minus 0.010 mm. fraction or by 8 percent of de-pebbled clay.

Particle size composition of clays and strength of minus 0.010 *mm. air-separated fractions.*—The data in tables 2 and 8 indicate that in general the air-separated minus 0.010 mm. fraction from a natural or de-pebbled clay containing a relatively large amount of minus 0.002 mm. material gave higher green compressive strengths to synthetic sands than did the minus 0.010 mm. fractions from clays containing less clay-sized material. As the minus 0.002 mm. fraction contains most of the clay mineral material present in the original sample this may be interpreted to mean that the greater the percentage of clay mineral material the greater is likely to be the green compressive strength imparted by the minus 0.010 mm. air-separated fraction. In the case of dry compressive strength, the minus 0.010 mm. fraction separated from a clay containing much clay mineral material gave generally lower strengths than the minus 0.010 mm. fractions obtained from more silty clays.

Similar relations of compressive strength to particle size composition and amount of clay mineral material also have been noted for the natural and de-pebbled surface clays. Apparently the size composition of the minus 0.010 mm. fraction reflects to a considerable degree the size composition of the original clay from which it was separated.

Influence of clay mineral composition.—The minus 0.002 mm. fractions of the air-separated gumbotils and related clays have been shown by a combination of optical, X-ray, and thermal analyses to contain mixtures of the clay minerals illite, kaolinite, halloysite, and montmorillonite. As in the case of the natural and de-pebbled surface clays, it was not possible to determine accurately the relative proportions of the various clay minerals, and therefore it is not now possible to relate the variation in bonding ability of the several samples to differences in kind and relative amount of the clay mineral constituents, although such differences probably do have an effect on the bonding ability.

TABLE 7.—RESULTS OF BONDING TESTS

Sample No.	Clay percent	Water percent	Green compressive strength lb. per sq. in.	Dry compressive strength lb. per sq. in.	Green permeability
Commercial bonding clays					
A	8	4.5	11.5	114.4	
		3.6	13.9	82.8	
		2.7	18.2	55.6	
		2.3	14.1	40.8	
		1.7	9.7	17.5	
B	8	4.0	2.9	50.3	
		3.1	5.0	38.7	
		2.4	7.5	24.8	
		1.8	9.2	15.3	
		1.3	7.8	7.6	
C	8	4.0	3.6	96.6	
		3.3	5.7	68.2	
		2.4	10.0	38.8	
		1.8	12.8	30.5	
		1.5	12.1	17.0	
D	8	4.0	3.8	36.8	
		3.2	5.7	34.9	
		2.4	8.1	20.3	
		1.8	8.7	14.2	
		1.3	7.2	6.5	
Southern bentonite	4	4.6	3.6	61.6	
		3.2	4.9	51.4	
		2.1	8.2	36.3	
		1.2	12.9	8.3	
Western bentonite	4	4.3	3.9		
		3.1	4.4	>93.5	
		2.1	5.3		
		2.0	5.6	74.8	
		1.1	9.4	13.9	
Till					
48	8	3.6	1.4		
		3.1	2.4		
		2.3	3.2		
		1.1	4.0		
Gumbotil					
18	8	3.5	1.4		
		3.0	2.0		
		2.1	2.8		
		1.3	3.6		
Loess					
49	8	3.7	2.1	101.3	
		2.9	3.1	67.5	
		1.8	4.9	32.7	
		1.2	5.0	4.6	

TABLE 7.—RESULTS OF BONDING TESTS—CON'T.

Sample No.	Clay percent	Water percent	Green compressive strength lb. per sq. in.	Dry compressive strength lb. per sq. in.	Green permeability
Lake clays					
3	8	3.9	2.1		
		3.3	3.3		
		3.2	3.5	86.2	
		2.6	5.1		
		2.4	5.4		
		2.3		51.8	
		1.8	6.9		
		1.7		35.2	
		1.2	7.7	22.3	
53	8	3.7	2.4	118.5	
		2.9	4.0	76.4	
		2.0	6.8	39.1	
		1.2	5.8	8.6	
150	8	5.0	1.5		
		3.8	1.8		
		3.1	2.5		
		2.2	2.8		
		1.3	4.5		
Residual clays					
8	8	5.6	1.8		
		4.0	2.4		
		3.4	4.0	58.1	
		3.3	4.1		
		2.5	6.4		
		2.4	6.8	28.1	
		2.2		32.9	
		1.9	9.4		
		1.8		20.7	
		1.2	11.2	7.3	
21	8	5.5	1.8		
		4.1	3.0		
		3.4		41.3	
		3.2	5.0		
		2.4		22.3	
		2.3	10.0		
		1.9		11.4	
		1.8	14.1		
		1.4		4.6	
		1.3	8.9		
24	8	3.8	2.0		
		3.1	2.5		
		2.3	3.3		
		1.7	4.6		
		1.1	7.0		
31	8	4.2	2.4	135.7	
		3.2	3.9	90.5	
		2.4	6.7	46.6	
		1.9	9.9	31.2	
		1.6	10.2	25.7	

Table 7.—Results of Bonding Tests—Con't.

Sample No.	Clay percent	Water percent	Green compressive strength lb. per sq. in.	Dry compressive strength lb. per sq. in.	Green permeability
Residual clays—Concluded					
44	8	5.0	1.4		
		3.4	2.5	101.1	
		3.3	2.5		
		2.5	4.0	54.0	
		2.4	4.1		
		2.2		47.5	
		2.0	6.4		
		1.8		30.1	
		1.3		20.2	
		1.2	8.9		
50	8	3.2	3.2	49.0	
		2.2	5.5	26.1	
		1.8	8.4	14.9	
		1.3	6.7	4.0	
52	8	4.3	3.1	42.6	
		3.2	5.0	30.2	
		2.2	9.3	17.0	
		1.7	11.1	8.7	
		1.3	7.4		
Other clays					
4	8	3.9	3.6	93.7	
		3.4	4.9	61.9	
		2.5	7.7	36.4	
		1.7	10.9	21.6	
		1.4	9.4	12.7	
45	8	4.0	2.1		
		4.0	2.2	117.0	
		3.5	3.2	78.5	
		3.3	2.6		
		2.5	5.7	46.2	
		2.5	5.0		
		2.0	8.1		
		1.8	9.9	15.2	
		1.8		20.0	
		1.4	8.1	5.8	
54	8	4.0	2.2		
		4.0	2.0		
		3.3	4.2		
		3.2	4.2	35.1	
		2.8	6.4	26.7	
		1.8	10.3	13.4	
		1.4	8.3	9.5	
Clay concentrates					
3	8	3.3	9.1		
	4	5.0	<1.0		
		3.9	1.4	69.9	
		2.9	2.7	39.7	
		1.9	4.1	29.0	
		1.0	5.5	4.6	

TABLE 7.—RESULTS OF BONDING TESTS—CON'T.

Sample No.	Clay percent	Water percent	Green compressive strength lb. per sq. in.	Dry compressive strength lb. per sq. in.	Green permeability
Clay concentrates—Concluded					
18	8	3.6	14.5		
	4	5.2	2.0		
		4.1	2.6		
		3.4	4.2	51.2	
		2.8	4.7		
		2.1	6.9		
		2.0	6.0	25.9	
		1.1	9.0	7.0	
150	8	3.3	15.9		
	4	4.1	2.4		
		3.2	4.5	40.3	
		3.0	4.4		
		2.1	7.3	19.9	
		1.1	8.7	7.1	
Air-separated fractions, minus 0.010 mm. size					
18	8	3.9	5.5	144.4	
		2.7	9.5	87.1	
		1.9	14.8	45.8	
		1.3	15.1	18.8	
		1.2	4.1		
		1.1	4.3		90
18	4	3.6	2.5	90.3	
		2.4	2.5	58.9	
		1.6	4.1	32.6	
		1.1	4.3		
55	8	3.9	4.7	87.9	
		2.9	9.4	72.1	
		2.2	14.5	48.1	
		1.4	15.3	21.9	85
		1.2	9.3	10.7	
55A	8	3.9	3.2	102.3	100
		2.8	6.0	72.8	95
		2.0	8.7	36.5	100
		1.4	9.7	20.9	90
		1.1	9.2		60
56	8	3.4	5.2	134.0	
		2.5	8.1	86.9	
		1.9	12.7	55.9	
		1.3	15.1	33.2	85
		0.9	8.4		
57	8	3.9	2.6	132.7	
		2.9	4.1	94.5	
		2.3	6.2	74.7	
		1.3	8.9	15.9	85
		1.2	7.3	10.0	
58	8	3.8	5.8	78.1	
		2.8	11.3	46.1	
		2.0	17.9	29.0	
		1.4	15.6	13.6	85
		1.0	6.8		

TABLE 7.—RESULTS OF BONDING TESTS—CON'T.

Sample No.	Clay percent	Water percent	Green compressive strength lb. per sq. in.	Dry compressive strength lb. per sq. in.	Green permeability
Air-separated fractions, minus 0.010 mm. size—Concluded					
58A	8	3.8	3.8	118.3	115
		2.7	7.5	65.5	115
		2.1	11.1	39.9	120
		1.8	12.3	33.9	130
		1.4	14.2	15.2	100
		1.1	10.5		70
59	8	3 9	6.7	173.9	
		2.7	10 6	99.7	
		2.1	16.8	57.7	
		1.4	16.4	30.5	95
		1.1	12.8	12.8	
59A	8	3.7	4.0	99.8	110
		2.6	8.0	63.0	110
		1.9	10.8	41.3	115
		1.4	12.0	26.0	100
		0.9	9.7		70
60	8	3.6	4.1	110.6	
		2.6	7.3	73.4	
		2.0	11.0	62.4	
		1.3	13.6	30.9	95
		1.0	7.3	6.5	
61	8	3.6	5.6		
		2.6	9.6		
		1.9	14.0		
		1.7	15.5	47.5	135
		1.3	16.0	31.4	90
		1.0	10.5		
62	8	3.8	5.1		
		2.7	8.4		
		1.9	12.8		
		1.4	13.3	40.7	120
		1.0	10.7		
Air-separated fractions, minus 0.050 mm. size					
18	8	3.9	2.6	147.1	
		2.9	4.0	101.9	
		2.2	6.2	55.1	
		1.3	8.4	16.0	
		1.1	7.8	6.5	55
		0.9	3.6		
55A	8	2.7	4.4	60.2	140
		2.1	6.3		140
		1.5	8.1	17.5	90
		1.1	7.3	10.6	90
		0.9	6.3		
58A	8	2.7	3.7	65.9	140
		2.0	6.7	39.1	140
		1.5	10.2	23.7	100
		1.1	7.7	7.4	105
		0.9	3.5		

Table 7.—Results of Bonding Tests.—Concluded.

Sample No.	Clay percent	Water percent	Green compressive strength lb. per sq. in.	Dry compressive strength lb. per sq. in.	Green permeability
Air-separated fractions, minus 0.050 mm. size—Concluded					
59	8	4.2	4.2	185.7	
		3.1	5.8	120.1	
		2.2	9.0	82.2	
		1.4	13.0	24.3	
		1.1	8.6	7.0	55
		0.9	5.1		
59A	8	2.9	3.7	62.1	90
		1.5	7.3	25.2	85
		1.3	7.9	18.1	70
		1.0	7.2	7.9	45
62	8	4.0	2.2	185.4	
		3.1	3.1	123.9	
		2.3	3.9	73.5	
		1.3	7.7	24.1	
		1.1	6.5	8.3	55
		0.8	3.4		
Air-separated fractions, plus 0.050 mm. size					
18	20	3.8	7.3	154.3	110
		2.7	11.8	88.2	120
		1.9	15.6	39.8	100
		1.3	6.3		21
55A	20	3.0	1.7	62.6	130
		1.7	2.9	28.3	130
		1.2	3.9	14.4	80
		0.9	3.3	4.9	60
58A	20	3.0	2.4	92.8	90
		1.6	5.5	27.4	85
		1.3	6.4	14.5	75
		1.0	5.5	3.6	60
59	20	3.6	7.6	178.3	130
		2.6	12.2	110.6	150
		1.9	17.3	61.5	120
		1.3	10.5	11.2	45
59A	20	2.8	1.7	48.7	110
		1.4	3.1	14.1	105
		1.2	3.2	10.0	105
		1.1	3.1	6.9	65
62	20	3.7	5.9	194.7	70
		2.6	9.3	119.1	70
		1.9	13.7	56.7	55
		1.3	8.1	9.6	20

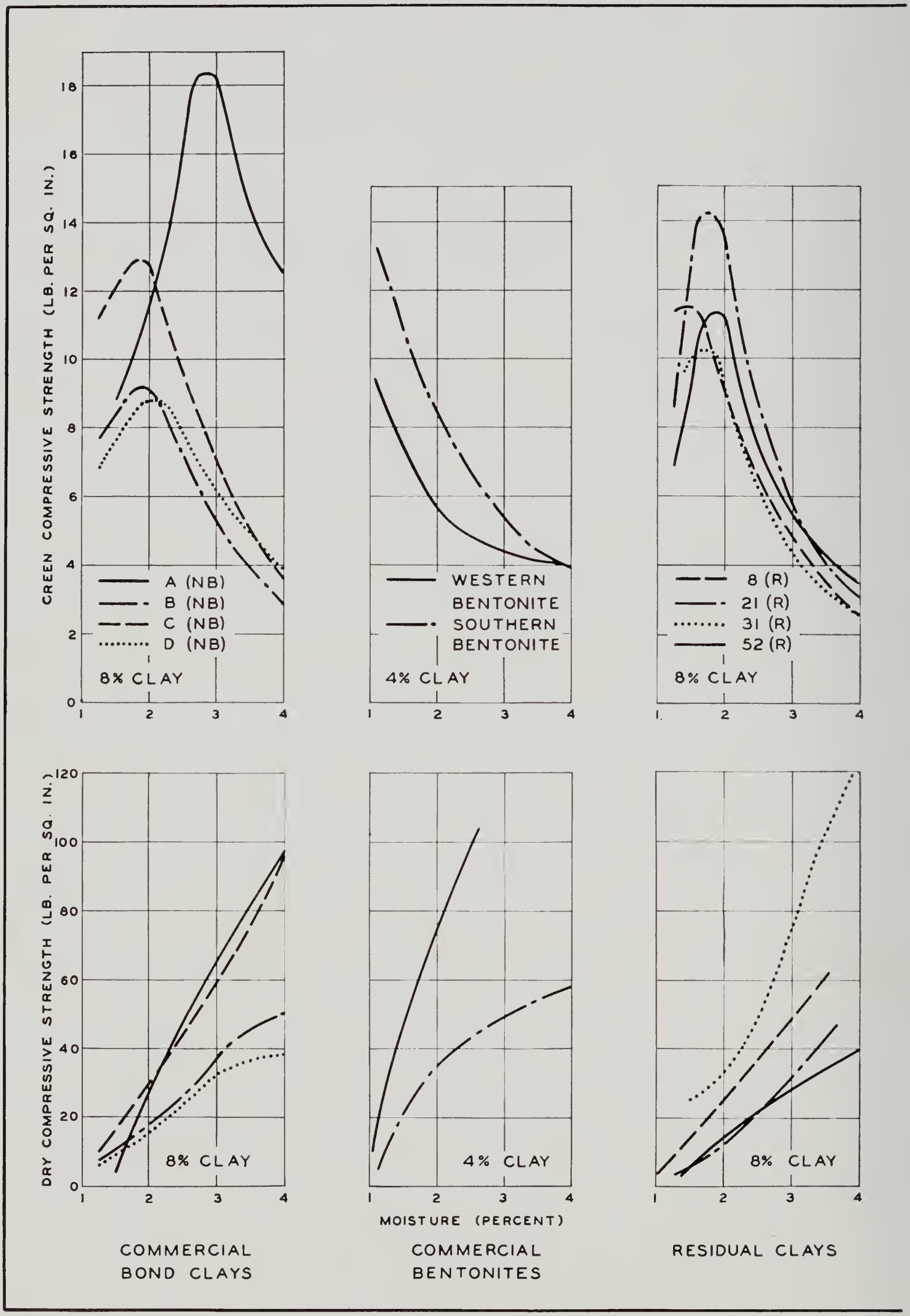

Fig. 2A.—Curves showing green and dry compressive strengths (at various moisture contents) of synthetic sands containing commercial bond clays, bentonites, and surface clays.

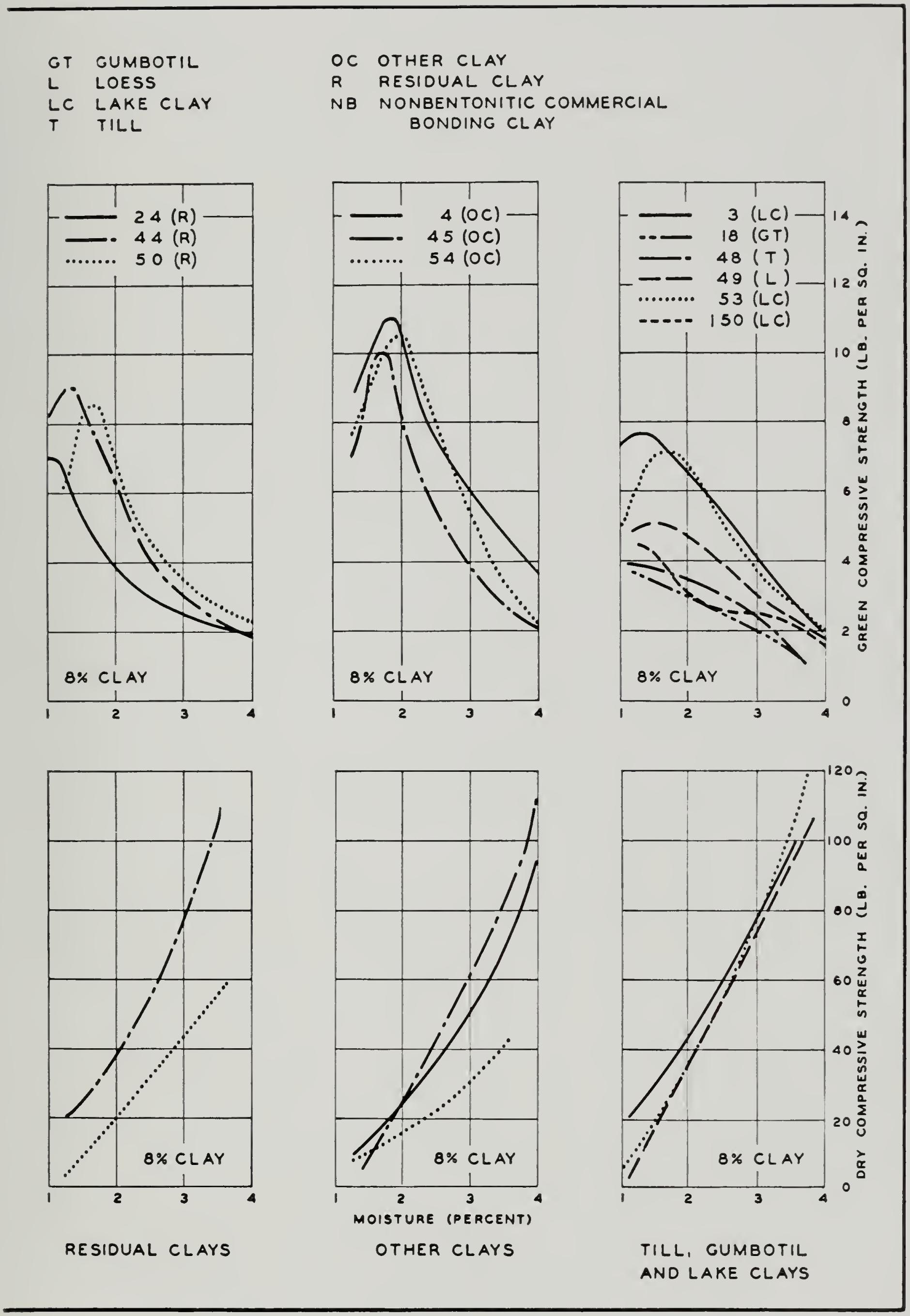

FIG. 2A.—Curves showing green and dry compressive strengths (at various moisture contents) of synthetic sands containing commercial bond clays, bentonites, and surface clays.

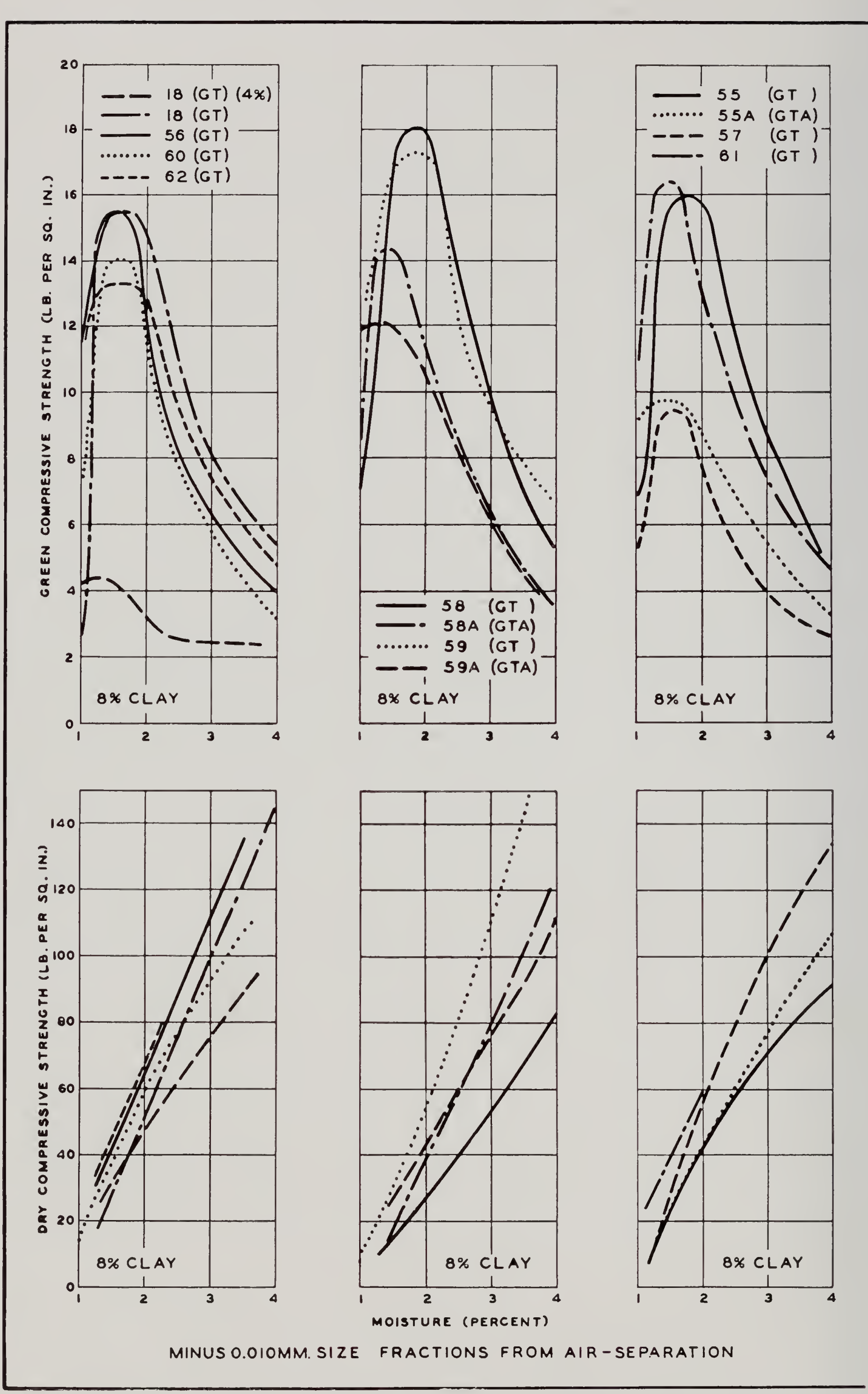

Fig. 2B.—Curves showing green and dry compressive strengths (at various moisture contents) of synthetic sands containing air-separated fractions and clay concentrates.

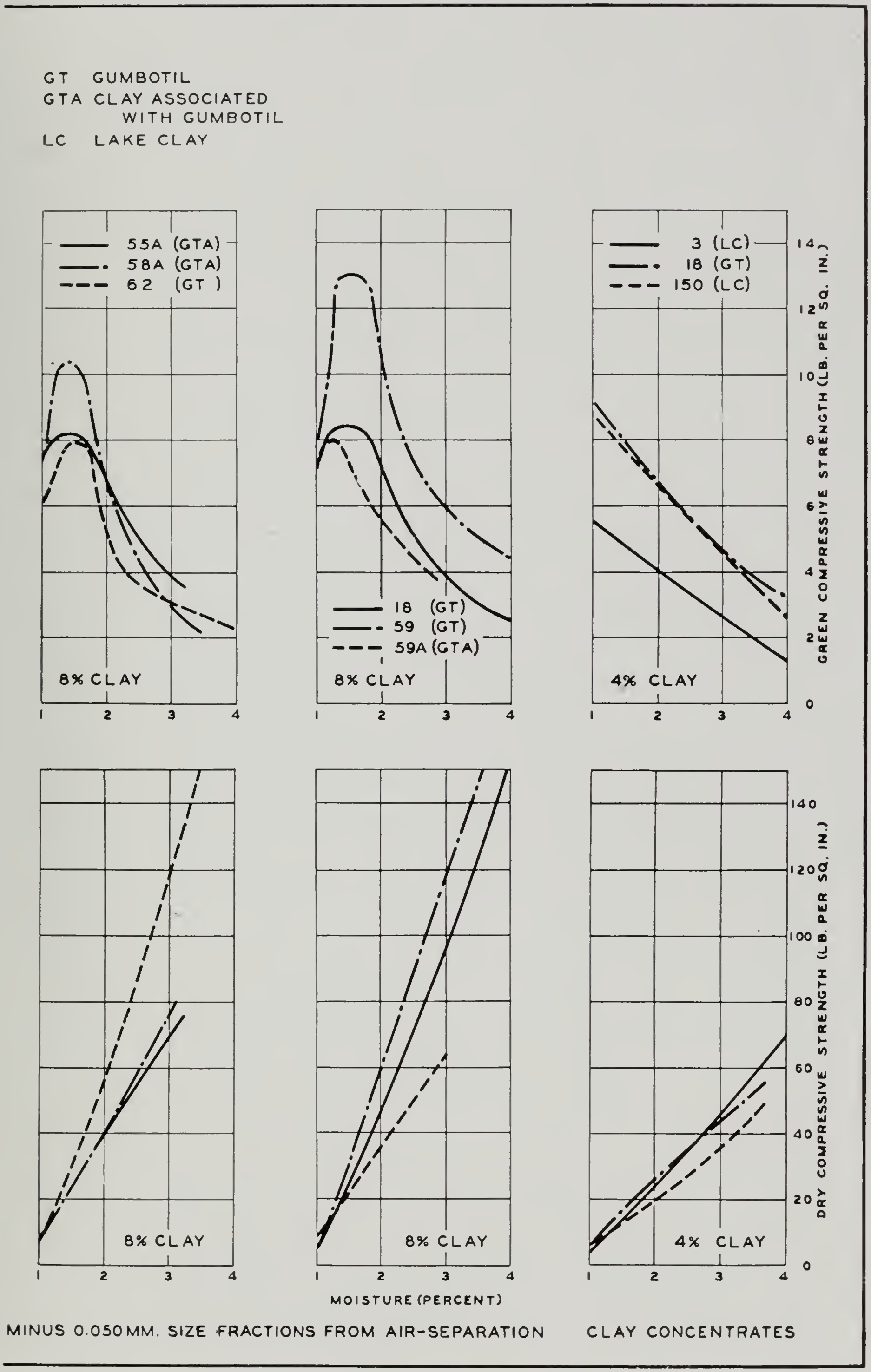

FIG. 2B.—Curves showing green and dry compressive strengths (at various moisture contents) of synthetic sands containing air-separated fractions and clay concentrates.

TABLE 8.—STRENGTH DATA AT COMPARABLE MOISTURE CONTENTS[1]

Sample No.	Type of clay[2]	Clay used percent	Green compressive strength in lb. per sq. in. at given percent moisture[3]						Dry compressive strength in lb. per sq. in. at given percent moisture[4]					Green permeability for the moisture content closest to optimum
			1.5	2.0	2.5	3.0	3.5	4.0	1.5	2.0	2.5	3.0	3.5	
Commercial bonding clays														
C	NB	8	12.0	12.5	9.5	7.0	5.0	3.5	16	30	45	60	75	
A	NB	8	9.0	11.5	16.5	18.0	14.5	12.5	5	28	49	65	82	
B	NB	8	8.5	9.0	7.5	5.0	4.0	3.0	11	19	26	37	46	
D	NB	8	7.5	9.0	8.0	6.0	5.0	4.0	9	15	24	32	37	
Southern bentonite	B	4	11.0	8.5	6.0	5.5	4.5	4.0	20	35	43	50	54	
Western bentonite	B	4	7.5	5.5	5.0	4.5	4.0	4.0	46	75	98			
Surface clays—natural or de-pebbled														
21	R	8	12.5	13.5	8.5	6.0	4.0	3.0	6	13	22	32	43	
52	R	8	9.5	11.0	7.5	5.5	4.5	3.5	5	14	21	28	33	
4	C	8	10.0	10.5	7.5	6.0	5.0	3.5	14	25	37	51	70	
54	C	8	8.5	10.5	8.0	5.5	3.5	2.0	10	15	22	30	41	
8	R	8	11.5	9.0	6.5	5.0	3.5	2.5	14	24	35	48	60	
31	R	8	10.0	9.0	6.0	4.5	3.5	2.5	25	33	50	77	104	
45	G	8	9.0	8.0	5.5	4.0	2.5	2.0	8	25	42	61	84	
50	R	8	8.5	7.0	4.5	3.5	3.0	2.5	9	20	32	43	55	
53	LC	8	7.0	7.0	5.0	4.0	3.0	2.0	20	37	55	79	105	
44	R	8	8.5	6.5	4.0	3.0	2.5	2.0	25	38	56	80	105	
3	LC	8	7.5	6.5	5.5	4.0	3.0	2.0	30	43	60	78	97	
49	L	8	5.0	4.5	4.0	3.0	2.5	2.0	17	36	55	74	95	
24	R	8	5.5	4.0	3.0	2.5	2.0	2.0						
48	T	8	4.0	3.5	3.0	2.5	1.5							
150	LC	8	4.5	3.0	2.5	2.5	2.0	1.5						
18	GT	8	3.5	3.0	2.5	2.0	1.5							
Clay concentrates—water-separated minus 0.002 mm. fractions														
18	GT	4	8.0	6.5	5.5	4.5	4.0	3.0	16	26	35	44	53	
150	LC	4	7.5	6.5	5.5	4.5	3.5	2.5	13	20	28	36	45	
3	LC	4	5.0	4.0	3.5	2.5	2.5	1.0	14	25	36	48	58	

Air-separated minus 0.010 mm. size fractions from gumbotils and associated clays

58	GT	8	17.0	18.0	13.5	10.0	7.0	5.0	16	28	40	54	68	85
59	GT	8	17.0	17.0	12.5	9.5	7.5	6.5	33	56	83	115	145	95
55	GT	8	15.5	16.0	12.0	9.0	6.5	4.5	25	42	58	72	83	85
18	GT	8	15.5	14.5	12.0	8.0	6.5	5.5	28	50	75	99	122	90
61	GT	8	16.5	13.0	10.0	7.5	6.0		40	60				90
62	GT	8	13.5	12.5	9.5	7.5	6.0	5.0	45					120
56	GT	8	15.5	12.0	8.0	6.5	5.0	4.0	40	65	87	110	134	85
58A	GTA	8	14.0	11.0	8.5	6.5	4.5	3.5	20	39	60	80	101	100
60	GT	8	14.0	11.0	7.5	6.0	4.5	3.0	37	59	76	93	107	95
59A	GTA	8	12.0	10.5	8.0	6.0	4.5	3.5	28	44	60	77	93	100
55A	GTA	8	9.5	8.5	7.0	5.5	4.0	3.0	22	43	59	77	93	90
57	GT	8	9.5	8.0	5.5	4.0	3.0	2.5	29	55	80	100	119	85
18	GT	4	3.5	3.0	2.5	2.5	2.5		31	47	62	75	88	

Air-separated minus 0.050 mm. size fractions from gumbotils and associated clays

59	GT	8	13.0	11.0	7.5	6.0	5.0	4.5	30	60	90	118	146	55
18	GT	8	8.5	7.0	5.0	4.0	3.0	2.5	24	46	70	97	125	55
58A	GTA	8	10.0[5]	6.5	4.5	3.0			24	40	58	76		100
55A	GTA	8	8.0	6.5	5.0	4.0			23	39	54	69		90
62	GT	8	8.0	5.5	3.5	3.0	2.5	2.0	30	55	87	120	151	55
59A	GTA	8	7.5	5.5	4.5	3.5			23	37	50	65		70

Air-separated plus 0.050 mm. size fractions from gumbotils and associated clays

59	GT	20	15.5	17.0	12.5	10.0	8.0	6.5	29	64	100	138	175	120
18	GT	20	11.5	15.5	13.0	10.5	8.5	6.5	19	45	75	105	135	100
62	GT	20	13.5	13.0	9.5	7.5	6.5	5.5	26	65	105	144	183	55
58A	GTA	20	6.0	4.5	3.5	2.5	2.0		25	45	68	93	115	75
55A	GTA	20	3.5[5]	2.5	2.0	1.5	1.5		23	35	49	63	78	80
59A	GTA	20	3.0	2.5	2.0	1.5			18	30	42	54		105

[1] Data on strengths taken from curves shown in figs. 2A and 2B. data on permeability from table 7.
[2] B—bentonite; C—Cretaceous clay; G—glacial clay; GT—gumbotil; GTA—clay associated with gumbotil; L—loess; LC—lake clay; NB—nonbentonitic commercial bonding clay; R—residual clay; T—till.
[3] Given to the nearest 0.5 lb.
[4] Given to the nearest 1.0 lb.
[5] Optimum occurs at lower moisture content.

Table 9.—Index to Samples

Sample No.	Kind of clay	Nearest town	County
3	Lake	Karnak	Pulaski
4	Cretaceous	Grand Chain	Pulaski
8	Residual	Mermet	Massac
18	Gumbotil	Louisville	Clay
21	Residual	Eichorn	Hardin
24	Residual	Kampsville	Calhoun
31	Residual	Council Hill	Jo Daviess
44	Residual	Stockton	Jo Daviess
45	Glacial	Stockton	Jo Daviess
48	Leached till	Chicago Heights	Cook
49	Loess	Bartonville	Peoria
50	Residual	Eichorn	Hardin
52	Residual	Eichorn	Hardin
53	Lake	Harrisburg	Saline
54	Cretaceous	Anna	Union
55	Gumbotil	Marshall	Clark
55A	Gumbotil	Marshall	Clark
56	Gumbotil	Montrose	Cumberland
57	Gumbotil	Toledo	Cumberland
58	Gumbotil	Brownstown	Fayette
58A	Gumbotil	Brownstown	Fayette
59	Gumbotil	Brownstown	Fayette
59A	Gumbotil	Brownstown	Fayette
60	Gumbotil	Walnut Hill	Marion
61	Gumbotil	Swanwick	Perry
62	Gumbotil	Kinmundy	Marion
150	Lake	Gilberts	Kane

Table 10.—Green Compressive Strengths of Several Clays and of the Corresponding Clay Concentrates

Sample No.	Amount of minus 0.002 mm. material in sample percent	Amount of ground sample used in bond tests percent	Moisture content percent	Green compressive strength lb. per sq. in.
3, natural	35.6	8	3.3	3.3
3, clay concentrate	100.0	8	3.3	9.1
18, de-pebbled	31.4	8	3.6	1.4
18, clay concentrate	100.0	8	3.6	14.5
150, natural	35.3	8	3.3	2.4
150, clay concentrate	100.0	8	3.3	15.9

TABLE 11—GREEN AND DRY COMPRESSIVE STRENGTHS IMPARTED BY SAMPLE 18 AND BY VARIOUS SIZE FRACTIONS DERIVED FROM IT

Type of material	Amount of material in original sample—percent	Amount of material used for each test—percent	Green compressive strength in lb. per sq. in. at indicated percent moisture						Dry compressive strength in lb. per sq. in. at indicated percent moisture				
			1.5	2.0	2.5	3.0	3.5	4.0	1.5	2.0	2.5	3.0	3.5
De-pebbled clay	99	8	3.5	3.0	2.5	2.0	1.5						
Minus 0.010 mm. fraction from air-separation	39	8	15.5	14.5	12.0	8.0	6.5	5.5	28	50	75	99	122
		4	3.5	3.0	2.5	2.5	2.5		31	47	62	75	88
Minus 0.050 mm. fraction from air-separation	72	8	8.5	7.0	5.0	4.0	3.0	2.5	24	46	70	97	125
Plus 0.050 mm. fraction from air-separation	27	20	11.5	15.5	13.0	10.5	8.5	6.5	19	45	75	105	135
Minus 0.002 mm. clay concentrate from water-separation	31	4	8.0	6.5	5.5	4.5	4.0	3.0	16	26	35	44	53

ILLINOIS SURFACE CLAYS AND BENEFICIATION

The data previously given on samples of various types of Illinois surface clays indicate that certain of them may be useful in their natural state as bonding clays whereas others require various amounts of beneficiation to bring them to their optimum condition. Although these data apply to a limited number of samples it is believed that the following generalizations may be made regarding the surface clays found throughout Illinois and their need for beneficiation.

Leached glacial till and gumbotil and associated clays commonly contain relatively large amounts of silt and sand plus some pebbles. In their natural state the clay mineral material in these clays, which is the effective bonding agent in them, is too diluted by the sand, silt, and pebbles to produce useful bonding strengths. However, in the case of several samples studied, removal of these diluting grains down to 0.010 mm. in size leaves a clay-rich material having good to superior bonding ability. Similar treatment doubtless would considerably improve other clays of this general type. Thus it appears that in general the commercial use of till, gumbotil, and associated clays is apt to depend in part upon their being beneficiated by suitable processes to eliminate the pebbles, sand, and much of the silt.

Leached loess clays are of variable composition but usually are characterized by a relatively high silt content, a low sand content and few, if any, pebbles. Here again the clay mineral material is diluted by silt and sand, and although the natural clays may be expected to give moderately high dry compressive strengths and low green compressive strengths, it is believed that the green strength would be increased by processing to remove most of the silt.

Leached lake clays as a rule contain no pebbles and only a relatively small amount of sand, but like loess they are high in silt. Tests on three samples show that lake clays in their natural state may be expected to impart low to medium green compressive strengths and high dry strengths. Elimination of silt and sand from laboratory samples yielded a product which had green strengths comparable to the bentonites tested as a standard in this work. Thus it is believed that lake clays in general will be improved as bonding clays by the elimination of all or much of their sand and silt content.

Residual clays are of diverse kinds. Some are high in clay mineral materials and may be used in the natural state for bonding clays. Others are sandy or silty and may be improved by processing to remove these diluting materials. One of the most common undesirable materials in residual clays is chert. When fragments of chert occur in important amounts their removal will facilitate the preparation of the clay for the market and will improve the quality of the finished product.

Cretaceous clays include both sandy and silty clays and also clays which are low in these constituents and therefore suitable for use as bonding clays in their natural state. The use of the varieties requiring processing would therefore seem to be unjustified.

The choice of methods for beneficiating Illinois surface clays to remove nonclay substances will depend on many diverse factors. However, it is believed there exist tried methods, including pneumatic and hydraulic classification, by which the desired aims may be accomplished.

APPENDIX

Description of Deposits Sampled

SAMPLE 3

Lake Clay

Cen. S. line SE. 1/4 SW. 1/4 SE. 1/4 sec. 26, T. 14 S., R. 2 E., Pulaski County

About two miles southeast of Karnak, 5½ feet of tough waxy noncalcareous silty clay from which sample 3 was taken, is exposed in the east bank of a drainage ditch known as Post Creek Cutoff. The noncalcareous clay stratum is covered by 7 to 10 feet of silt and is underlain by calcareous clay. The 7 to 10 feet of silt overburden probably was overcast when the ditch was dug, and it is believed that the normal overburden on the noncalcareous clay is about 1 to 2 feet of silt and silty soil. A large quantity of noncalcareous clay is believed to be available in adjoining areas.

SAMPLE 4

Cretaceous Clay

Cen. S. line SW. ¼ SW. ¼ sec. 27, T. 14 S., R. 2 E., Pulaski County

In a ditch and beneath the ditch bottom along an east-west road about two miles east of Grand Chain occur the following strata:

	Ft.
6. Loess	8
5. Gravel, composed of chert pebbles partly cemented with iron oxide	2
4. Clay, gray and brown mottled, noncalcareous	3
3. Clay, gray, plastic, noncalcareous, lower 2 feet somewhat browner	10
2. Clay, brown, and silt, brown and yellow, interbedded, both noncalcareous	3
1. Iron crust	

Strata 4, 5, and 6 crop out in the sides and bottom of the ditch; strata 1, 2, and 3 were explored with a soil auger. Because stratum 4 is closely similar to stratum 3 except in color, it was mixed with the latter in the proportion of 3 parts to 10 parts to form the composite sample referred to in this report as sample 4.

The clay is of Cretaceous age and crops out on the west slope of an irregular ridge which trends approximately north-south. The deposit probably caps most of the ridge, and other deposits like it may cap similar hills and ridges in the vicinity. The loess and gravel overburden is probably thickest on the crest of the ridge and thinner on its flanks. It is believed, however, that a considerably quantity of clay may be available in the vicinity of the outcrop with an average of 10 to 15 feet of overburden.

SAMPLE 8

Residual Clay

E. line, SE. ¼ NE. ¼ sec. 22, T. 14 S., R. 3 E., Massac County

Red cherty clay overlying the Ste. Genevieve limestone is exposed in a cut along the Chicago, Burlington & Quincy Railroad about one mile north of Mermet. It ranges up to 3 feet in thickness and is overlain by 8 feet or more of loess and possibly a thin layer of brown cherty gravel. The top of the ridge to the west of the outcrop is about 25 feet above the clay exposed in the cut, and a greater thickness of clay might be revealed by exploration there.

SAMPLE 18

Gumbotil

SE. cor. SW. ¼ NE. ¼ sec. 35, T. 5 N., R. 6 E., Clay County

In a road-cut on the east side of Panther Creek about four miles north of Louisville, 3½ feet of gumbotil is exposed, from which sample 18 was taken. The gumbotil is overlain by 1½ to 2 feet of soil and silt and underlain by gumbo sand. The appearance of a considerable number of additional exposures of gumbotil in the general vicinity of the sampled outcrop suggests that the upland flats of the area are probably underlain by 2 to 4 feet of gumbotil having 3 to 5 feet of overburden. A large tonnage of gumbotil appears to be available in this general area.

SAMPLES 21, 50, AND 52

Residual Clays

Secs. 26, 35, and 36, T. 11 S., R. 7 E., Hardin County

Samples 21, 50, and 52 were all taken from the same general locality and are therefore discussed together. Sample 21 was obtained from an outcrop in the cen. S. ½ S. ½ SW. ¼ SE. ¼ sec. 26 in a gully on the west side of State Highway 34 and 2.3 miles north of Eichorn. The strata exposed are as follows:

	Ft.	In.
Soil		6
Silt, brown, clayey; probably loess	6	
Gravel, angular, brown and yellow chert		6–9
Clay, red, plastic; contains a few chert fragments (Sample 21). A yellow zone occurs about 3½ feet below the top	7	
Clay, mottled red and reddish brown, silty, firm; contains scattered chert fragments	3	
Covered		

The deposit occurs on the north slope and some distance below the crest of a roughly east-west ridge underlain by the St. Louis limestone. As much as 5 feet of red clay may lie between the bottom of the exposed strata and the top of the underlying limestone. The thickness of the silty overburden probably increases toward the crest of the ridge. It is believed possible, however, that a relatively large tonnage of clay with an overburden 10 feet thick or less may be available along the ridge.

About ¼ mile southwest of the above outcrop, in the NW. ¼ NW. ¼ NE. ¼ sec. 35, sample 50 was taken from an outcrop of 6½ feet of red clay that contains chert fragments, especially in its upper 3 feet. The overburden consists of 2 feet of lighter colored silty clay, followed above by a 1 foot layer of chert pebbles which is capped by 1 foot of brown silt. This sample is from the same deposit of clay as sample 21 but is not necessarily residual from the same limestone strata. At the outcrop limestone does not appear below the clay, but in a nearby test pit, located higher on the hillside, limestone is reported to have been encountered beneath 10 to 15 feet of red clay.

Sample 52 was obtained in the NW. ¼ NW. ¼ NW. ¼ sec. 36 from a deposit of red clay containing chert fragments varying locally in abundance. Exposures occur in several road-cuts along the northeastern slope of a ridge. The maximum thickness of red clay observed was 6 feet, and sample 52 represents this thickness of clay. The overburden is brown silt approximately 1 foot thick. The clay is believed to have been formed from the St. Louis limestone and hence to be related to the clay in the deposit from which samples 21 and 50 were obtained. Numerous outcrops of similar red clay in several gullies in the NE. ¼ sec. 35, T. 11 S., R. 7 E., indicate that much of the surrounding area is underlain by red clay, a considerable part of which may have 10 feet or less of overburden.

SAMPLE 24

Residual Clay

NE. ¼ SW. ¼ SW. ¼ sec. 4, T. 9 S., R. 2 W., Calhoun County

Eight feet of cherty red clay, probably developed from the Burlinton limestone, is exposed in a ditch along a gravel road west of Kampsville. The outcrop is in the north end of a gently sloping hill, the top of the hill being about 75 feet above the level of the outcrop. The overburden on the clay is clayey silt 3 feet or more thick. This outcrop and numerous others nearby suggest that there is a considerable quantity of similar residual clay in the area.

SAMPLE 31

Residual Clay

Cen. SE. ¼ SW. ¼ sec. 30, T. 29 N., R. 2 E., Jo Daviess County

At this locality 1 to 3 feet of the reddish-brown, noncherty clay underlying 1½ feet of clayey silt crops out in a cut on the south side of a road. This clay is thought to have been derived from the Galena dolomite which is exposed immediately under the clay near the place where the sample was taken. The thickness of the clay probably exceeds 3 feet at places. The deposit occurs on the gently sloping east side of a ridge which trends roughly northwest. Council Hill Station on the Illinois Central Railroad is half a mile south of the sampled locality. Other deposits of the same kind of residual clay are exposed in other road-cuts in the vicinity and a considerable tonnage of clay may be available with less than 5 feet of overburden.

SAMPLE 44

Residual Clay

SW. cor. NW. ¼ NE. ¼ sec. 23, T. 27 N., R. 4 E., Jo Daviess County

A road-cut about 70 yards long along State Highway No. 78 about 1½ miles south of Stockton exposes a maximum of 4 feet of red noncherty clay resting on the Galena dolomite. The overburden consists of 1 to 3 feet of soil and silt. Other outcrops in the vicinity suggest that a deposit of workable size may be present in this area.

SAMPLE 45

Glacial Clay

SW. ¼ NW. ¼ NE. ¼ sec. 3, T. 26 N., R. 4 E., Jo Daviess County

About 5 miles south of Stockton on State Highway No. 78, a cut-bank along the west side of Plum River exposes the following strata:

	Ft.	In.
Soil, black	1	
Clay, light yellowish-brown, calcareous	3	6
Clay, brown and dark red, noncalcareous; contains a few pebbles of worn chert (Sample 45)	4	
Limestone		

The clay stratum from which sample 45 was taken is of uncertain origin. It may be an old glacial till from which weathering has eliminated all calcareous material or possibly a water-laid clay of glacial origin. Although the extent of the deposit is not definitely known, an area of 100 acres or more situated between the main course of Plum River and the valley of Middle Fork may be underlain by noncalcareous clay of a generally similar nature.

SAMPLE 48

Till

NE. cor. NW. ¼ SE. ¼ sec. 16, T. 35 N., R. 14 E., Cook County

In the bank of a ditch near Chicago Heights, 2 feet of sandy, pebbly noncalcareous till, from which sample 48 was taken, is exposed below 10 inches of soil. The noncalcareous till grades downward into calcareous till which also contains a greater proportion of pebbles. A large

quantity of material similar to sample 48 is available in the vicinity of the sampled locality.

Samples of noncalcareous till could have been obtained at many places in northern Illinois, but the above site was selected because it is near Chicago and also near deposits of sand which may have value as molding sand but are low in natural bond.

SAMPLE 49

Loess

SE. ¼ NE. ¼ sec. 26, T. 8 N., R. 7 E., Peoria County

Sample 49 was taken from an exposure half a mile southwest of Bartonville and approximately 150 yards north of a main road. It represents 2 feet 8 inches of noncalcareous loess having an overburden of 1 foot of soil. Large quantities of similar loess are available.

SAMPLES 51 AND 52

(See Sample 21)

SAMPLE 53

Lake Clay

Cen. S. ½ SW. ¼ sec. 15, T. 9 S., R. 6 E., Saline County

Sample 53 was taken from 30 inches of dark gray plastic noncalcareous silty clay covered by about 1 foot of soil which was exposed in a ditch, now filled in, on the south edge of Harrisburg. At the base of the bed of noncalcareous clay is a zone 3 inches thick containing numerous nodules of impure calcium carbonate. Buff or gray calcareous silty clay lies below this zone. It is believed that the noncalcareous stratum may possibly extend over a large part of the flat area lying east and southeast of Harrisburg and that a large tonnage of this material may be available.

SAMPLE 54

Cretaceous Clay

Sec. 35, T. 11 S., R. 2 W., Union Co.

This sample is white kaolin from a commercial pit near Kaolin Station. The clay is probably of Cretaceous age and occurs in bodies which are believed to occupy depressions in the surface of the bedrock. The deposits contain white, pink, bluish-gray, or chocolate-colored clays which are noncalcareous and plastic. Although in general free from impurities, the deposits locally contain lignitic material and in places layers or irregular masses of sand. The overburden is chiefly sand, gravel, and loess ranging from 5 to about 40 feet in thickness.

In recent years clay has been mined commercially in the area by W. E. Kreitner and Kreitner Kaolin Co., both of Cairo, and by the Southern Illinois Minerals Co. of Murphysboro, and by the Eastern Clay Products Co., Eifort, Ohio. Part of the Eastern Clay Products Company's production is reported to have been bonding clay.

Because of the irregular shape of the clay bodies and the possible variability in the character of the clay, careful prospecting is recommended to determine their extent and character. The deposits are located near the Gulf Mobile and Ohio Railroad. Detailed descriptions of the occurrence and characteristics of kaolin may be found in publications of the Survey and elsewhere.[1]

SAMPLES 55 AND 55A

Gumbotil

NW. ¼ SW. ¼ NW. ¼ sec. 27, T. 11 N., R. 12 W., Clark County

The following succession of beds is exposed in a roadcut on the north side of U. S. Highway No. 40 where it descends the east bluff of Mill Creek approximately two miles southwest of Marshall:

	Ft.	In.
Soil, buff, silty	1	2
Silt, gray to light buff, silty, becoming pebbly toward base	3	6
Gumbotil, gray and buff mottled, sandy, more pebbly, noncalcareous (Sample 55)	3	
Till, gray and buff mottled sandy, more pebbly, noncalcareous (Sample 55A)	2	8
Till, grayish-brown, sandy, very pebbly, calcareous	15	
Road level		

Much of the same sequence of beds is exposed in other cuts southwest along the same highway, and it is probable that gumbotil underlies sizable areas of flat upland in the vicinity.

SAMPLE 56

Gumbotil

SW. ¼ NW. ¼ NW. ¼ sec. 13, T. 9 N., R. 7 E., Cumberland County

Sample 56 was taken from a 5-foot thickness of noncalcareous clay exposed in a cut along the east side of a road about four miles north of Montrose. Above the clay is 2 feet, 2 inches of grayish-brown silt overlain by 2 feet of buff silty soil. Below the clay is a 1– to 4–inch heavily iron-stained zone succeeded by 5 feet of grayish-brown calcareous till. It is believed that the upper 3 feet of the sampled bed is gumbotil and that the lower 2 feet is the noncalcareous clay which characteristically occurs between the gumbotil and the underlying calcareous till. Extensive flat areas extending north and east suggest the probable existence of an abundance of material like that sampled.

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[1] Parmalee, C. W., and Shroyer, C. R., Further investigations of Illinois fireclays: Illinois Geol. Survey Bull. 38D, 1921, pp. 43-63.

Piersol, R. J., Lamar, J. E., and Voskuil, W. H., Anna "kaolin" as a new decolorizing agent for edible oils: Illinois Geol. Survey, Rept. Inv. No. 27, 1933.

Grim, R. E., Petrology of the kaolin deposits near Anna, Illinois: Econ. Geology, vol. 29, No. 7, Nov. 1934, pp. 659-670.

SAMPLE 57

Gumbotil

Near cen. S. line, SE. ¼ sec. 30, T. 10 N., R. 8 E., Cumberland County

A cut along the north side of State Highway No. 121 in the east bluff of a small creek about five miles west of Toledo exposes 4 feet of gray and buff mottled silty gumbotil from which sample 57 was taken. The gumbotil is overlain by 20 inches of dark buff silt and above this 8 inches of brown sandy soil. Beneath the gumbotil appears 5 feet of very pebbly, yellow and gray, noncalcareous till and below that 3 feet of calcareous till. A large quantity of similar gumbotil probably underlies the flat areas which continue to the east and south.

SAMPLES 58 AND 58A

Gumbotil

West line, SW. ¼ NW. ¼ NW. ¼ sec. 14, T. 7 N., R. 2 E., Fayette County

Samples 58 and 58A were taken from an exposure of glacial clay in a cut along the east side of a gravel road about four miles north of Brownstown.

	Ft.	In.
Soil, dark gray to dark buff	1	3
Gumbotil, gray and brown mottled, sandy, contains a few small pebbles (Sample 58)	2	
Till, gray and brown mottled, more sandy and pebbly than the gumbotil, noncalcareous (Sample 58A)	3	
Till, gray to chocolate-brown, calcareous	4±	
Till, brownish-gray, calcareous, hard	5	
Covered		

Numerous other road-cuts in this vicinity show from 2 to 3½ feet of gumbotil under 1½ to 2 feet of soil and silt overburden, and it appears likely that a considerable amount of gumbotil is available.

SAMPLES 59 AND 59A

Gumbotil

SW. ¼ SE. ¼ NW. ¼ sec. 14, T. 6 N., R. 2 E., Fayette County

An outcrop along the east side of a gravel road in the north bluff of a small creek approximately two miles south of Brownstown exposes the following beds:

	Ft.	In.
Soil, dark gray to gray	3	4
Gumbotil, brownish-gray above, mottled gray and brown below, sandy, pebbly (Sample 59)	2	6
Till, gray to brown, noncalcareous, more sandy and pebbly than the gumbotil (Sample 59A from uppermost 3½ feet)	4	4
Covered		

An extensive flat upland north of this outcrop is probably underlain by the same type of gumbotil.

SAMPLE 60

Gumbotil

Near cen. N. line, NW. ¼ NW. ¼ sec. 4, T. 1 S., R. 2 E., Jefferson County

Sample 60 is from 33 inches of gray silty gumbotil appearing in an outcrop on the south side of a gravel road some 50 feet west of the bridge over a shallow creek, about three miles east of Walnut Hill. The overburden consists of 20 inches of buff to gray silt overlain by 6 inches of soil. Below the gumbotil is exposed about 12 inches of noncalcareous till, browner and more pebbly than the gumbotil.

The land surface east and south of the sampled outcrop is gently rolling and probably underlain by gumbotil. Outcrops visible eastward along the road show a greater thickness of overburden, and it seems probable that the usual thickness of overburden in this general area is 4 feet or more.

SAMPLE 61

Gumbotil

Near cen. E. line, NE. ¼ NE. ¼ NE. ¼ sec. 33 T. 4 S., R. 4 W., Perry County

This outcrop is situated on the west side of a gravel road in the south valley wall of a shallow gully about 1½ miles south of Swanwick. Sample 61 represents 28 inches of mottled gray and brown pebbly gumbotil. It is overlain by 44 inches of gray to buff noncalcareous silt and 10 inches of soil. About 10 inches of noncalcareous gray till is exposed beneath the gumbotil.

Similar exposures in several nearby road-cuts show about the same thickness of gumbotil under 4 to 5 feet of overburden, and it is probable that this relation exists over a sizable area.

SAMPLE 62

Gumbotil

Cen. N. line, NW. ¼ SE. ¼ sec. 25, T. 4 N., R. 2 E., Marion County

Sample 62 was taken from 30 inches of gray pebbly gumbotil in an exposure on the south side of a gravel road near the top of the east valley wall of a shallow gully about 3½ miles west-southwest of Kinmundy. From 24 to 28 inches of gray to buff soil and silt occurs above the gumbotil, and 8 inches of noncalcareous gray till succeeded by 14 inches of mixed gray and buff slightly calcareous till lies below it.

Large quantities of gumbotil like sample 62 are probably available from extensive flat uplands in the vicinity of the sampled deposit.

SAMPLE 150

Lake Clay

SE. ¼ NW. ¼ NW. ¼ sec. 24, T. 42 N., R. 7 E., Kane County

The abandoned pit of the Walker Clay Products Co. at Gilberts exposes 2½ feet of gray and brown, noncalcareous, silty clay from which sample 150 was obtained. The overburden consists of 14 inches of black soil. A considerable quantity of this clay is believed to be available in the vicinity of the pit.

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